



CIRCULAR No. 494

NOVEMBER 1938

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.THE TEXAS LEAF-CUTTING ANT¹ AND ITS CONTROL

By E. V. WALTER, *associate entomologist*, LEE SEATON, *assistant scientific aide*,
and A. A. MATHEWSON,² *assistant entomologist*, *Division of Cereal and Forage*
Insect Investigations, Bureau of Entomology and Plant Quarantine

CONTENTS

	Page		Page
Introduction.....	1	Description of the nests—Continued.....	
Character of injury.....	2	Old nests.....	7
Food of the ants.....	2	Interior of the nest.....	7
The fungus.....	4	Control experiments.....	9
Life history.....	5	Laboratory experiments.....	9
Mating flight.....	5	Field experiments.....	10
Social castes.....	5	Time to apply treatment.....	14
Description of the nests.....	6	Myrmecophiles in the nest of <i>Atta texana</i>	14
Soil preferences.....	6	Summary.....	17
The new nest.....	6	Literature cited.....	18

INTRODUCTION

The fungus-growing ants, of which the most prominent species in the United States is the Texas leaf-cutting ant (*Atta texana* Buckley) are among the insects most destructive to agriculture in the tropical and subtropical parts of the Americas. Many other species of leaf-cutting ants of more or less economic importance are also found in these regions. These ants are so injurious in the Tropics that in some countries property owners are required by law to attempt their control. In parts of Brazil the materials necessary for control may be purchased at cost from Government agencies with funds loaned by the Government for this purpose. Fungus-growing ants are found from northern Texas to central Argentina. One unimportant small species is found along the Atlantic coast as far north as central New Jersey.

Townsend (11),³ in 1923, estimated the loss from these ants in North and South America at as much as \$1,000,000,000. Escherich (3), in 1929, reported the estimated loss in the State of Sao Paula, Brazil, alone to be 40,000,000 marks (\$10,000,000). In 50 Texas counties, surveyed in 1936 by R. R. Reppert, State extension entomologist, in cooperation with the country agricultural agents, the total annual loss was estimated to be approximately \$1,642,000, or about \$6 per nest. At that rate the total annual loss in the United States would be about \$5,000,000, since Reppert's survey covered less than one-third of the total area infested. The annual loss per nest ranges from \$3 to \$4 in cereal and forage crops to \$15 or more when the nests are in orchards or among fields of vegetables.

¹ *Atta texana* Buckley; order Hymenoptera, family Formicidae, subfamily Myrmicinae, tribe Attini.

² Separated from the service Sept. 15, 1935.

³ Italic numbers in parentheses refer to Literature Cited, p. 18.

Atta texana is by far the most important species of these ants in the United States. It is found quite commonly throughout Texas east of an imaginary line running from Wichita Falls to Del Rio, and southward into Mexico. T. E. Snyder, of the Division of Forest Insect Investigations, Bureau of Entomology and Plant Quarantine, writes in correspondence: "Personally I have found the ant fairly well distributed throughout central Louisiana, west of the Mississippi River." Nests have been observed by the writers within 5 miles of Texarkana, Tex., and others have been reported along the Red River in northern Texas. It is quite possible that they may occasionally be found in the adjacent areas of Oklahoma and Arkansas, although definite records of such occurrence are not at hand.

The literature on *Atta texana* is very meager. Except for mere mention in a few books on general entomology, a few short articles in farm magazines, and a record by Jones (5) of its occurrence in Louisiana, the only references of any note seem to be a paper by Hunter (4) in which he briefly discusses the habits of this species, two considerable works by Wheeler (12, 13) giving the biology of the several species of fungus-growing ants in the United States in some detail, and a recent article by Snyder (9) describing the injury to young pines in Louisiana and giving recommended control measures. The closely related species *A. insularis* Guer, which occurs in the West Indies, has, however, received some attention, and two other species, *A. sexdens* (L.) and *A. cephalotes* (L.), have been the subjects of considerable research in Central and South American countries (2, 8, 11), with Brazil perhaps taking the lead in control research.

It is of interest to note that one of the earliest quarantines issued against any insect in American territory referred to *Atta insularis* in Puerto Rico (6).

CHARACTER OF INJURY

Atta texana does its greatest damage by cutting green vegetation, which it carries into its nest. Few plants are immune to its attack. The authors have never observed this species gathering leaves from plants having a milky juice, although several South American writers mention other leaf-cutting ants as pests of the Para rubber trees. After they have once attacked a plant they seldom stop until it is stripped of its foliage. Large trees are defoliated in a remarkably short time and smaller trees and shrubs are often denuded in a single night. The persistence of the ants in returning to the same plant or plant species is the basis of the common belief that they will use only one kind of plant at a time. The foliage and tender green stems are cut off in pieces as large as one ant can carry. These sections of leaf, from three-eighths to one-half inch in diameter and many times the weight of a single ant, are held upright over the head and transported thus to the nest. This habit has given rise to the name "parasol ant," which is occasionally used for members of this genus.

FOOD OF THE ANTS

The use made of these leaf fragments was for a long time a mystery. It was generally supposed that they were eaten, and this idea is still

prevalent. It is now known, however, that they serve as the medium upon which the ants cultivate a fungus which constitutes their only food. Belt (1), in 1874, seems to have been the first to suspect the true use of the leaf cuttings. In 1892 Tanner (10) reared a closely related species in artificial nests in Trinidad and was the first to prove that not only the adults but also the larvae feed on a fungus grown on this material.

After the pieces of leaves are carried into the nest they are cut into smaller pieces and placed in special chambers having an average capacity of about 1 gallon, and in these the fungus gardens are maintained. The leaf fragments are built up loosely and soon ferment to a light-brown color until the entire mass looks much like a large sponge covered with a white fungus (fig. 1). This arrangement gives the



FIGURE 1.—A small fungus garden showing the spongelike arrangement of the plant material covered with the white mycelium. $\times \frac{2}{3}$.

maximum surface area for the production of the fungus and permits the easy passage of the ants in their efforts to keep out undesirable growths. After the fresh material has undergone proper fermentation and become brown, the white strands of fungus begin to grow on it. The small ants of the "gardener" caste also gather bits of the fungus and scatter them on this new medium.

In spite of the fact that spores of many kinds of fungi must be carried into the nest on the leaves and on the bodies of the ants themselves, only the one desired species of fungus is ever allowed to develop as long as ants are present to tend the garden. On a number of occasions during the present studies portions of these gardens were removed and stored in closed tin cans at the laboratory. So long as there were a number of ants present to tend the garden, only one species of fungus developed, but after the ants were killed or removed several other fungi quickly appeared, thus indicating that the absence of other fungi was due to the care given by the ants.

THE FUNGUS

The fungus appears as a mass of fine, short, white threads which rather thickly cover the material upon which it is growing. It soon depletes the food value of the medium so that the older parts of the mass show relatively little of the white threads of mycelium. As the fungus ages it produces numerous spherical terminal dilations of hyphae from one-fourth to one-half millimeter in diameter (fig. 2). These swellings are particularly numerous in the older parts of the garden, and it is upon these special growths that the ants feed. Möller (?) showed that these special growths are not produced when the fungus is grown in a pure culture apart from the influence of the ants.

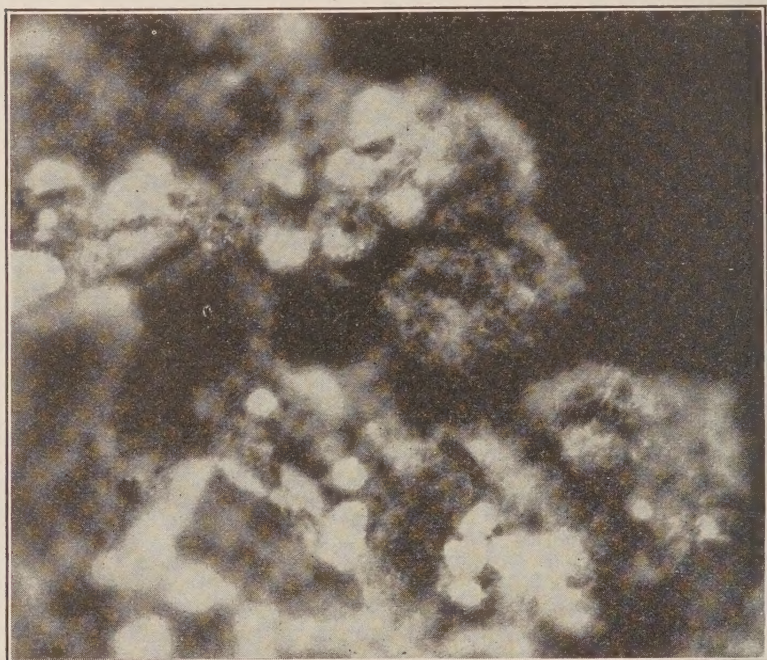


FIGURE 2.—A small portion of a fungus garden showing the short white threads of mycelium which cover the spongelike mass of leaves, and the enlarged growths upon which the ants feed. $\times 16$.

He therefore considered that the ants are in some way responsible for the development of the growths.

Möller also attempted to determine the systematic position of the fungus, even though he failed to grow the fruiting forms from his cultures. On four occasions, however, he found an undescribed mushroom with a wine-red cap and stem growing in abandoned nests of *Acromyrmex* sp. and called it *Rozites gongylophora*. From the basidiospores of this mushroom he grew a mycelium that resembled that found in the nests of the ants, and he was able to get three species of *Acromyrmex* to eat this mycelium and the cap and stem of the mushroom. On this basis he believed he had established the identity of the fungus. There are several weaknesses in Möller's work, however,

and it appears that there should be further research before the identification is positively accepted. (See Wheeler (12, 13).)

LIFE HISTORY

The life history of this ant is perhaps not so well known as it should be. Young are produced throughout the year, although in smaller numbers late in the fall and during the winter than in the warmer months. The sexual forms are produced early in the spring. Mature larvae and pupae of the sexual forms were found in the vicinity of San Antonio, Tex., on March 14, and adult sexual forms were found on April 1. The newly matured sexual forms may stay in the parental nest for a considerable time. In 1935 a few had left by May 10, but most of them were still there as late as June 4, when these studies were terminated.

MATING FLIGHT

The mating flight ordinarily takes place during the early part of a clear, moonless night in May or June. From April 15 to June 3, 1935, the writers had five, and part of the time seven, nests under observation at San Antonio every night when the weather was favorable, but no large flight was observed from these nests during that time. On clear nights, with no rain in prospect, the entrances were enlarged to two or three times normal size. A few young females appeared at the entrances soon after dark. The males appeared about a half hour later. After a few minutes they returned within the nest and others came out. By about midnight all sexual forms had returned inside the nest and the workers covered the openings with trash and closed the tunnels down to normal size by filling them with moist soil from below. The sexual forms were so sensitive to light that a passing beam from a flashlight would send them scurrying into the nest. Very few appeared at the entrances on bright moonlight nights.

H. B. Park, of the Texas Apicultural Laboratory at San Antonio, told the writers of a swarm of the sexual forms striking against his house about 9 o'clock one night, and of finding the dead ants in a mass where the swarm had alighted on the ground. He described the numbers as very great, and the mass as having at a distance the size and appearance of the disintegrated carcass of a small red calf.

SOCIAL CASTES

No effort was made to determine the number of castes or the functions of all those found in the nest. The largest workers, which are comparatively few in numbers, seem to be of the soldier caste, whose duty it is to protect the nest. They are scarcely more ferocious, however, than are the ants of the other large castes, although their jaws are somewhat more powerful. The next three or four smaller sizes cut the foliage and carry it into the nest. Those of the smallest size seem to be the gardeners. They are so numerous and so solicitous in the care of the fungus that it is difficult to free even a small portion of the garden of these little ants. Individuals of the next larger size seem to comprise the nurse caste, that care for the young. They

are assisted in this work by some of the larger ants. Other castes probably assist with the work within the nests (fig. 3).

The soldiers and other large workers are extremely pugnacious, attacking with their powerful jaws anything disturbing the nest. They are so tenacious in their hold that they will often hang on for hours unless forcibly removed. The writers have had clothing go through the laundry and come out with the heads of these ants still attached. The gardeners and nurses are much less aggressive than the larger forms and seldom take any part in the defense of the nest.

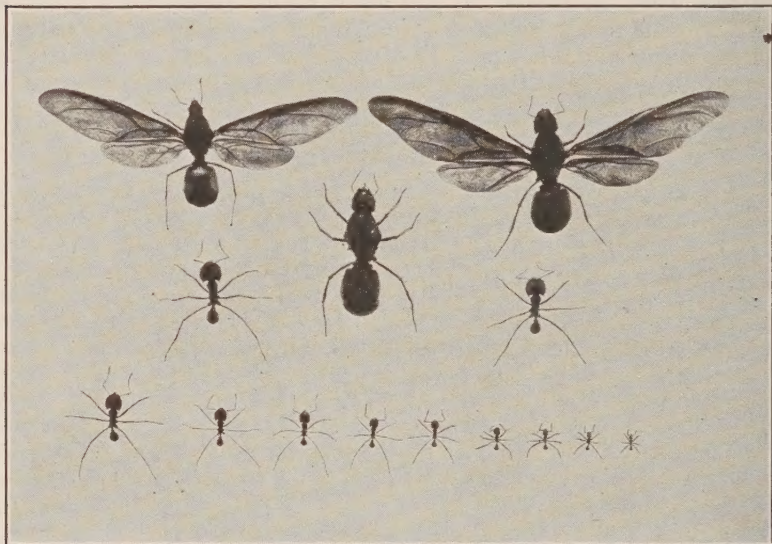


FIGURE 3.—The various castes and sizes found in a nest of *Atta texana*. The workers of the various sizes are shown without any effort to differentiate the castes. An old queen, taken during the winter, is shown at the center, a virgin queen at the upper right, and a male at the upper left. All $\times 0.84$.

DESCRIPTION OF THE NESTS

SOIL PREFERENCES

The Texas leaf-cutting ant seems to prefer to construct its nests in a somewhat sandy soil, although the nests are by no means restricted to this type. Wheeler (12, 13) found that a sandy surface soil underlaid with a stratum of clay beneath which the nests were constructed was a favored soil type. That this ant is not confined to the sandy soils, however, is evident from the fact that many nests have been observed in the heavy, waxy soils of central Texas and even in the cedar-covered rocky hills of the Edwards Plateau section in central Texas. The nests are often constructed near the base of a tree so that the roots help in supporting the soil over the galleries.

THE NEW NEST

A number of new nests constructed by young females were located on May 13 and 14, 1935. These could be identified on the surface by a 4-inch ring of loosely packed pellets each about a quarter of an

inch in diameter around the entrance. The tunnels were plugged so tightly that it was difficult to follow them when digging out the nest. Judging from an examination of the new nests found, the tunnel generally goes downward to a depth of from 14 to 16 inches, then turns horizontally an inch or so before terminating in a somewhat flattened spherical chamber about $1\frac{1}{4}$ inches in diameter.

The only food taken into the new nest is a small pellet of the fungus, which is carried by the female in her buccal pouch. This is divided and spread on the moist floor of the cell and carefully tended by the female until her young have matured and are able to gather green material with which to start the garden.

OLD NESTS

A number of queens may be found living in the same nest. During the winter the ants are more or less concentrated in its center, and the surface area of the nest is then relatively small. As the season grows warmer, the queens separate to more distant parts of the nest, each accompanied by a number of the workers and soldiers. The nest then shows a much larger surface area. These migrating queens usually colonize in the immediate vicinity, so the surface gives the appearance of a single colony. On two occasions a subsidiary nest with a connecting runway was found at a distance of 75 yards. Others have been found at shorter distances. Twelve nests measured during the summer showed an average area of 1,455 square feet and ranged from a small nest of about 100 square feet to one covering 3,000 square feet. The amount of soil excavated was estimated, after measuring its depth and area, at an average of 80 cubic feet per nest. Two other nests showed areas of 4,425 and 4,500 square feet and the soil excavated therefrom amounted to 1,600 and 225 cubic feet, respectively.

The surface area over the nest is thickly covered with low mounds from 12 to 24 inches in diameter and up to 5 or 6 inches in height (fig. 4). Those directly over a center of activity are usually circular, with the entrance at the center, but the more distant ones are likely to be crescent-shaped with the opening at one side, or are sometimes higher on one side than on the other.

The surrounding area for a distance of sometimes as much as 300 feet is more or less thickly pierced with entrances to underground runways through which the ants carry material to the nest. Paths on the surface often extend the feeding area much farther, so that cutting is sometimes done 400 or 500 feet away even though the same species of plants may be found growing almost directly over the nest.

INTERIOR OF THE NEST

The interior of the nest consists of a series of spherical or obovoid chambers of various sizes (fig. 5), most of which, during the summer, are filled with the spongy fungus gardens. In winter some of the more distant ones may be vacant. One nest, in an angle formed by a steep creek bank and an equally steep ravine, and dug out during the winter, showed a surface area of about 600 square feet and had

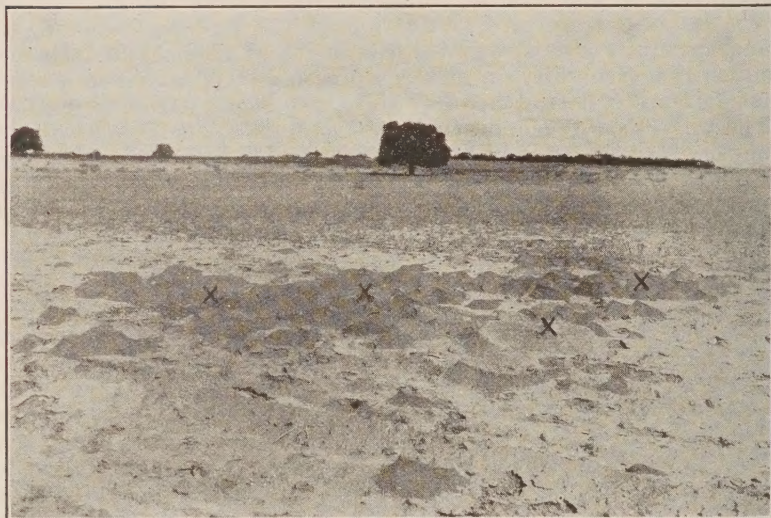


FIGURE 4.—A nest of medium size in a plowed field. This nest was about 30 feet across. It shows four centers of activity (marked with x's), each of which had to be treated to kill out the colony.

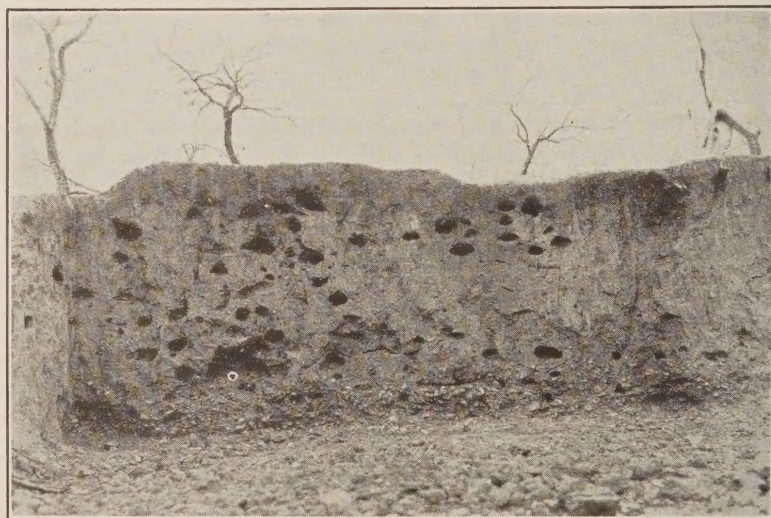


FIGURE 5.—A cut through the center of a nest of *Atta texana*. The fungus gardens were removed so that the cavities would show better in the photograph. The nest at this point was 8 feet deep.

about 80 cubic feet of soil in the mound. A total of 911 cavities with an average capacity of 121 cubic inches were found. Of these, 638 were filled with fungus gardens, 233 were empty, and 40 near the bottom were filled with waste material and dead ants. There were probably a few additional cavities not dug out. When the plant material is no longer of value in the fungus gardens it is often carried to chambers deep in the nest and discarded there rather than outside. Ants that die in the nest are also disposed of in the same way. Approximately 2 quarts of dead ants were taken from one of these cemeteries in this nest. The nest extended to a depth of $9\frac{1}{2}$ feet, where a bed of coarse gravel was encountered. Some other nests, in sandy soil, were from 12 to 15 feet deep, and some have been reported as having a depth of 18 feet.

CONTROL EXPERIMENTS

LABORATORY EXPERIMENTS

Since the food of the leaf-cutting ant consists entirely of the fungus grown in the nest, it was considered possible to control the ant with a fungicide. Any satisfactory fungicide would have to be cheap, easy to use as a dust or gas, and stay in suspension in the air for sufficient time to penetrate to all parts of the nest. Bordeaux dust, 300-mesh dusting sulphur, vaporized sulphur, the fumes of burning sulphur, and carbon disulphide, commonly used as an insecticide, were the materials chosen as meeting these requirements, and these were tested in the laboratory as well as in the field.

A tight glass-sided box of 1-cubic-foot capacity was prepared in which to make laboratory tests of the foregoing materials. Fresh material from the fungus gardens was weighed out in 5-gram samples and spread in 100-mm Petri dishes. A number of ants were then introduced. In making the tests two of the prepared dishes were placed on the floor of the box and uncovered. The box was then closed and a known quantity of the dust was blown in at the top so as to create a fog, which was allowed to settle. Where sulphur vapor or fumes were used, known quantities of sulphur were vaporized or burned outside and the fumes forced into the box. The carbon disulphide was placed in open dishes in the box. After the dust or fumes had settled the dishes were covered and placed in an incubator for observation. Each treatment was repeated two or three times, making a total of four or six dishes used. The results of the replicated treatments are summarized in table 1. The percentage mortality of the fungus and of the ants is estimated.

The heavy sulphur dust settled quickly without reaching the lower parts of the fungus, but the fungicidal action continued for a considerable time. Bordeaux dust, on the other hand, remained in suspension for a considerable time, and there was still a noticeable quantity in the air at the end of 15 minutes. Such ready suspension in the air would seem to make it reach all parts of the fungus garden so that it would be ideal for the purpose. Such, however, was not the case. Fungus on the surface was readily killed by the bordeaux, but that on the under side or in protected places continued to grow. Sulphur vapor proved nearly three times as deadly to both ants and fungus as

did the fumes from an equal quantity of burning sulphur. Sulphur vapor was also four times as effective a fungicide as sulphur dust. Also, the sulphur dust did not kill the ants. Carbon disulphide was effective both as a fungicide and as an insecticide. It required nearly twice as strong a dosage of carbon disulphide to kill the ants as was necessary to kill the fungus.

TABLE 1.—*Effects of different concentrations of fungicides and insecticides per cubic foot on the fungus food and ants of Atta texana*

Material used	Concentration	Mortality of fungus after—			Mortality of ants after 18 hours ¹
		18 hours	48 hours	72 hours	
	Grams	Percent	Percent	Percent	Percent
Sulphur dust.....	0.1	5	20	40	0
	.2	20	75	90	0
	.3	85	95	100	0
	1.0	99	100	100	0
	1.5	99	100	100	0
Check ²	2.0	100	100	100	0
Sulphur fumes (burning sulphur).....	.6	0	0	0	0
	1.0	40	80	90	(3)
	1.5	80	95	95	100
Check ²		100	100	100	0
Sulphur vapor.....	.6	0	0	0	0
	1.0	100	100	100	100
	1.5	100	100	100	100
	2.0	100	100	100	100
Bordeaux dust.....	.6	0	0	0	0
	.8	40	40	⁴ 35	0
	1.0	60	60	⁴ 55	0
	2.0	70	70	⁴ 65	0
	2.5	80	80	80	0
	3.0	80	80	80	0
Check ²		85	85	85	0
Carbon disulphide.....	Cc	0	0	0	0
	.2	0	0	0	0
	.4	0	0	0	0
	.6	20	20	20	(3)
	1.0	100	100	100	(3)
	1.2	100	100	100	(3)
	1.4	100	100	100	100
Check ²	1.6	100	100	100	100
	2.4	100	100	100	100
	3.2	100	100	100	100
Check ²		0	0	0	0

¹ Examinations were also made after 43 and 72 hours, but no additional mortality was noted.

² Fungus increased in quantity in all checks.

³ Stupefied, but revived.

⁴ Fungus continued to grow on under side of material.

FIELD EXPERIMENTS

CALCIUM CYANIDE

Thirty nests, ranging in size from very small to large, were treated with calcium cyanide by blowing the dust into a number of the larger central openings with a pump such as is used for blowing the dust into burrows to kill rodents. Of this number, the colonies in only six very small nests appeared to be killed even though some were treated four or five times. A power duster was used on two nests of medium size. A hose from the duster was inserted in a hole that had been punched

in the nest to a depth of several feet, penetrating several cavities. Five pounds of calcium cyanide was used in each case, and the duster was operated for several minutes to insure as good distribution of the dust and gas as possible. All surface openings were closed to confine the gas. The colonies were weakened, but after a few weeks they appeared to be nearly as strong as at the beginning. The gas apparently did not reach all active centers.

SULPHUR DUST

Twenty-seven nests of various sizes were treated by blowing 300-mesh dusting sulphur into the nest at several places with a dust gun such as is used for killing rodents with calcium cyanide. The colonies in eight small nests appeared to be killed in from one to three treatments. No colonies in large nests were killed out entirely although all were much weakened. Because of the cheapness of the sulphur this method may occasionally be satisfactory for small nests.

BORDEAUX DUST

Twenty-three nests were treated with bordeaux dust blown into the nest as was done with sulphur dust. Of these, only five small to very small nests became inactive. Colonies in the others continued strong and in several cases increased in strength. It is believed that at least a part of those that became inactive were subsidiary nests and that the ants merely returned to the central nest. Bordeaux dust used in this way cannot be recommended. In one test A. A. Mathewson sprayed with bordeaux mixture some shrubbery which was being cut by ants. This treatment did not deter the ants or cause any noticeable effect on the colony. Bordeaux mixture thus applied would probably inhibit any fungus growth on the sprayed leaves, but the ants gather material from so many sources that it is doubtful whether any effective control could be secured in this way.

SULPHUR VAPOR AND FUMES

From laboratory tests it would appear that sulphur vapor and the fumes from burning sulphur would be excellent materials for the control of this ant because of the cheapness of the material used and the effectiveness of each form, both as a fungicide and as an insecticide. Several attempts were made to treat nests in this way using equipment manufactured for this purpose as well as some of the writers' own design. No entirely satisfactory equipment was found. The nests that were treated showed considerable weakening of the colonies, however, and it is believed that with satisfactory equipment for vaporizing or burning the sulphur and forcing it into the nest this method would be successful. It would, however, have the disadvantage of a high initial cost of equipment and the fact that considerable time would be required to treat each nest. The fumes from burning sulphur and a mixture of sulphur and arsenic are used to a considerable extent in several South American countries in the control of similar ants found

there, apparently with considerable success. In these countries both labor and sulphur are relatively cheap, while some other materials used in control are rather expensive.

CARBON DISULPHIDE

Carbon disulphide proved to be the most reliable material used in the tests as well as the easiest to apply. The cost of the material is a little high, but no equipment other than that normally available on the farm is necessary for its application.

Three methods of application were used, all of which were effective. The one most commonly used by the farmers and the one that seems to appeal to the imagination most is to pour from 1 to 3 quarts of the liquid into the nest, well distributed among the main entrances, and, after it has had a few minutes to evaporate, explode it by dropping a lighted match at one of the treated entrances. This method is effective but somewhat wasteful of material. The explosion adds an enjoyment to the proceedings, and farmers will sometimes use larger quantities of the material than necessary just to get a bigger explosion or will distribute it to more holes to hear it pop more often.

Another method is to dig a hole beside one or more of the most active entrances in each center of activity deep enough to allow a shallow pan containing the liquid, to be set in it and then cover the hole with something to keep out the wind. The quantity of material used in each pan would depend on the size of the nest and the number of pans used. Usually from $\frac{3}{4}$ to $1\frac{1}{2}$ pints was satisfactory. In this method less material is used than in any other, but there may not be the same certainty of killing the colony with the first treatment unless care is taken to reach all centers.

A third method, which proved to be surest of results with the first treatment, is to pour a few gallons of water down a large entrance in each of the active centers of the nest, to clear away any obstructions and prevent the soil from absorbing the carbon disulphide so readily, and follow this immediately with one-third to one-half a pint of carbon disulphide washed down with the last pailful of water.

In the treatment of 148 nests in cooperation with farmers, an average of 3.25 pints of carbon disulphide was used per nest when the material was exploded, 1.66 pints when it was placed in pans, and 1.74 pints when it was used with the water. By referring to table 2, however, it is seen that a much larger proportion of the nests were classed as medium to large in the series where the pan method was used than in the series using water. It is therefore evident that in the matter of material used the difference is somewhat more in favor of the pan method than the foregoing figures indicate. One reason for using more material with the water method and at the same time the probable reason for the more certain results was the tendency on the part of the operators to apply treatment at a larger number of places, thus being more sure of treating all centers. All of the methods in which carbon disulphide was used were effective. The differences in labor, costs of materials, and other matters have to be considered somewhat before a choice is made.

No specific studies were made to determine the effect of the carbon disulphide treatment on vegetation. It was frequently used, however, near, and occasionally directly under, shrubs (privet, roses, and other ornamentals) and small trees (oak, hickory, mesquite, fig, plum, and others) without any observed ill effect. No work was done near pine trees.⁴ In many cases carbon disulphide was used in pastures and grain fields without any observed injury to the vegetation. Weeds would often be growing directly over the pans when the results were checked a week or so after the application. In no case were ill effects observed on any vegetation except where the liquid was accidentally spilled full strength on tender grass. In the experimental work the liquid was placed beneath the surface of the soil and probably did not come in direct contact with the roots, but some of the gas may have permeated the soil as it diffused to lower levels through the tunnels constructed by the ants.

No tests were made to determine how soon after treatment an area could be safely planted to crops, but in view of the fact that no injury was ever observed to plants already growing on the ground at time of treatment it seems probable that crops could be safely planted on treated ground within a few hours after the gas had been applied.

TABLE 2.—Quantities of carbon disulphide required to kill out a colony in a nest of *Atta texana*

Method of using carbon disulphide	Size of nests		Average quantity of carbon disulphide used per nest
	Small	Medium to large	
	Number	Number	Pints
In pans.....	21	40	1.66
With water.....	46	27	1.74
Exploded.....	7	7	3.25

Carbon disulphide vapor, when mixed with air in certain proportions, is highly inflammable and explodes with considerable violence. Due care should be taken to see that no smoking is allowed near where the material is being used and that the fumes do not come in contact with any open fires or electric sparks. The liquid should be stored in tight containers in a cool place away from the sun. When carbon disulphide is being transported from place to place the container should be tightly stoppered and protected from the heat of the sun, otherwise enough gas may be liberated to cause an explosion.

⁴Observations and experiments on the control of the Texas leaf-cutting ant in the Kisatchie National Forest in Louisiana have been carried on by the Division of Forest Insect Investigations of the Bureau of Entomology and Plant Quarantine in cooperation with the Forest Service. No injury to pine trees or seedlings occurred after the use of carbon disulphide to control this ant when the chemical was applied to ant galleries approximately 10 feet apart by injecting it into the holes through a funnel with a 4- or 5-foot rubber-hose extension, the hose being inserted as deeply as possible before the carbon disulphide was poured in, and all holes, both treated and untreated, belonging to the colony being closed with the heel immediately after treatment. Two ounces of carbon disulphide, or slightly more, was applied in each hole.

In 1935 a committee was appointed by the Minister of Agriculture of Brazil to study the methods being used in that country for the control of the leaf-cutting ants. A total of 86 processes or kinds of material were tested, each being replicated five times. Several days after the test each nest was dug into to determine its condition. In concluding their report this committee says (2): "In final analysis carbon disulphide appeared to be the most efficient and practical of the formicides."

TIME TO APPLY TREATMENT

As has been shown, a nest may contain a number of females and their colonies widely scattered in the summer but concentrated in a small part of the nest during the winter, when as many as three females have been taken from a single cavity. It is thus evident that the treatment with carbon disulphide should be made as early in the year as it is warm enough for the liquid to evaporate readily, and before the queens leave the center of the nest to establish their individual centers of activity. In Texas these conditions are most likely to occur together from late in February to early in April. After that time the queens are likely to be more widely distributed, and consequently it is necessary to treat more places and use more material. Of 99 nest colonies treated with carbon disulphide between February 5 and April 16, 1935, 88 were apparently killed out with one treatment, 10 required two treatments, and 1 required three treatments. Final examinations for 1935 were made on June 2 and 3. Some of these nests were reexamined in June 1936, and all seen at that time were still inactive. In all cases occasional inspections should be made to be sure the colony has been completely destroyed.

MYRMECOPHILES IN THE NEST OF ATTA TEXANA

As occasion arose in these investigations, some effort was made to collect the insects and other forms of life occurring in the nests of the Texas leaf-cutting ant. The nest which was entirely dug out gave a good opportunity to add many species to those collected by digging into other nests. A total of about 50 species of insects and arachnids were taken from the various nests. Many of the insects were found in the nest refuse consisting chiefly of dead ants and plant material no longer useful in the production of fungus. As already mentioned, the ants store much of this waste material in the lower chambers instead of carrying it out of the nest. Several species, which were represented only by larvae or pupae, could not be determined. A few others were represented only by broken chitinous remains so that definite association could not be established. Several others, such as some of the crickets, sowbugs, and millipedes, which normally enter dark places to hide, are not included in the following list because they are not considered as being definitely associated with the ants or their nests. Those forms which appeared to be regular inhabitants of the nest are listed in table 3.

TABLE 3.—*Myrmecophiles found in nests of Atta textana*¹

Species	Approximate depth where found	Locality in Texas	Remarks
Sowbugs:	Feet		
<i>Platyarthrus scoblii</i> B. L.	1-10	San Antonio..	Small white form most common at 2 to 5 feet in chambers where ants were most active.
Pseudoscorpions:			
<i>Allochernes</i> , n. sp.	10	Boerne.	A number found in a chamber filled with waste material. First record of this genus in North America.
Spiders:			
<i>Cesonia bilineata</i> (Hentz)	3	San Antonio..	An immature stage from a fungus garden. Ants did not disturb it.
<i>Bothriocyrtum</i> sp.	2	do.	An immature female from a fungus garden.
<i>Cicurina arcuata</i> Keys.	7	do.	Adult male in nest refuse.
<i>Crammonota pictilis</i> Camb.	7	do.	Immature male in nest refuse.
Mites:			
<i>Typhlotrombidium tridentifer</i> (Ewing).	(?)	do.	Common on walls of chambers and around fungus gardens. Not disturbed by ants.
Trombidid, n. gen., n. sp.	6	do.	Under a fungus garden.
<i>Tarsonemus</i> , n. sp.	7	do.	Members of this genus ordinarily plant feeders, but this species found only on a small black beetle, <i>Gnathoncus</i> sp., in nest refuse.
<i>Macrocheles</i> sp.	7	do.	Found in nest refuse.
<i>Macrocheles</i> sp.	7-10	San Antonio and Boerne.	Do.
Macrochelinae, n. gen. n. sp.	10	Boerne.	Do.
Parasitid.	7	San Antonio..	Nymphs of undetermined genus and species found in nest refuse.
Tyroglyphid.	7-10	San Antonio and Boerne.	Nymphs of an undetermined genus and species on a beetle, <i>Gnathoncus</i> sp., and in nest refuse.
Thysanura:			
Near <i>Atelura</i>	(.)	do.	A small yellowish or nearly white degenerate species on walls of nearly every chamber, especially numerous around largest fungus gardens and where ants were most numerous. Quick to get out of the way of ants although the latter apparently did not molest them.
Collembola:			
<i>Pseudosinella violenta</i> (Folsom)	1½-10	do.	Usually in nest refuse but some taken in outlying vacant chambers. None taken where ants were abundant.
Orthoptera:			
<i>Arenivaga bolliana</i> (Sauss.)	7-10	do.	This large roach present in abandoned tunnels and in chambers filled with nest refuse.
<i>Arenivaga tonkawa</i> Heb.	7-10	do.	Same as preceding species.
<i>Attaphila fungicola</i> Wheeler.	(2)	do.	(2).
<i>Myrmecophila nebrascensis</i> Lugg.	(2)	do.	(4).
Coleoptera:			
<i>Eumierus</i> sp.	7-9	San Antonio..	Found in nest refuse.
Pselaphid, n. gen., n. sp.	7-9	do.	Do.
<i>Atheta</i> sp.	7-10	San Antonio and Boerne.	Do.
<i>Reninus salrini</i> Lewis?	7-9	San Antonio..	Do.
<i>Gnathoncus</i> sp.	7-9	do.	Do.
<i>Acrilus</i> sp.	7-9	do.	Do.
<i>Conoderus zysticus</i> (Cand.)	0-10	do.	1 adult captured as it was entering a nest. 1 adult and many fragments found in nest refuse.
Other elaterid adults.	7-10	do.	Many fragments of several unidentified species in nest refuse.
Elaterid larvae.	7-10	do.	In nest refuse. Some identified as belonging to tribe Steatoderini.
<i>Euphoriaspis aestuosa</i> (Horn)	8	Boerne.	(5).
<i>Cottinis longitarsis</i> Casey.	7-10	San Antonio and Boerne.	(5).
<i>Megalostomis major</i> (Crotch)	5-8	San Antonio..	(7).
<i>Hymenorus discretus</i> Casey.	7-9	do.	In nest refuse.
Lepidoptera:			
<i>Amydria confusella</i> Dietz.	1-8	do.	(8).

See footnotes on the following page.

TABLE 3.—*Myrmecophiles found in nests of Atta texana*—Continued

Species	Approximate depth where found	Locality in Texas	Remarks
Diptera:			
<i>Forcipomyia</i> sp.	Feet 7-10	San Antonio..	Reared from nest refuse.
<i>Sciara varians</i> Joh.	7-10	do.	Do.
<i>Phlebotomus</i> , n. sp.	(?)	do.	Reared from nest refuse. Adults also found throughout the nest but most numerous in cavities containing good fungus gardens and where ants were quite active.
<i>Megaselia</i> sp.	7-10	do.	Reared from nest refuse.
<i>Philygria fuscicornis</i> (Loew) ..	7-10	do.	Do.
<i>Milichia</i> sp.	7-10	do.	Do.
<i>Fannia</i> sp.	7-10	do.	Do.
Hymenoptera:			
<i>Galesus</i> , n. sp. near <i>punctiger</i> Fouts.	8	do.	Adults hard to capture because of small size and habit of crawling down into the refuse to hide. No apparent inclination to escape by flight.
<i>Scolia guttata</i> Burm.	0-8	San Antonio and Com-fort.	(?).
Hymenopteron.	8	San Antonio..	2 naked pupae about 1 inch long found in nest refuse. Adults failed to emerge.

¹ The identifications of the myrmecophiles listed were made by specialists in the Division of Insect Identification, Bureau of Entomology and Plant Quarantine.

² Found throughout the nests.

³ Wheeler (13, p. 396) says that the little roaches of the genus *Attaphila* are the only insects known to live on intimate terms with these ants. While the present studies have added many species to those previously known, none has been observed to have such cordial relationship with *Atta texana* as does this roach. It is yellowish brown and measures only 3 to 3.5 mm in length. Individuals were often seen to mount the backs of the soldiers or larger workers and groom them. Apparently they derive some food from the wax secreted by their hosts. The ants not only tolerate them but actually seem to enjoy being groomed by them. This roach is most abundant in those portions of the nest where the ants are most numerous and active.

⁴ This small cricket is about the size of the roach *Attaphila fungicola* just mentioned and also may be found grooming the ants. Apparently the continued scraping by the cricket soon becomes annoying and the ant either moves away or turns on the cricket, which nimbly hops away. The crickets do not climb on the backs of the ants as do the roaches, so have to content themselves with nibbling at the legs and other parts they can reach. They are also found nibbling at the walls of the chambers and runways which have become incrustured with the waxy secretions.

⁵ This adult scarabaeid was found apparently freshly emerged on March 14 in an abandoned chamber containing waste material. In this same chamber were a number of pupal cells containing prepupae that may have been of this species. The walls of the pupal cells were composed of a mixture of earth and waste material firmly cemented together. They were quite hard, nearly round, and about an inch in diameter. Specimens taken for rearing were lost when the underground rearing chamber became flooded one night during a heavy rain.

⁶ The larvae of the scarabaeid *Cotinis longitarsis* are often very abundant in the waste material in the lower levels of the nests. From 30 to 40 *C. longitarsis* grubs have been taken from a single chamber. They were of three sizes, possibly indicating a 3-year life cycle. This appears to be the only insect of economic importance found in the nests of *Atta texana*. The adults feed readily on ripening fruit and are often quite injurious. Judging by the abundance of the larvae in the ant nests examined, it is possible that these nests constitute the principal breeding place of this scarabaeid. It therefore seems possible that the control of the leaf-cutting ant might also control the fruit pest *C. longitarsis*.

⁷ The larvae of *Megalotomis major* are casebearers. Their cases, standing out from the walls of the runways like small rounded pegs, present one of the most curious features in the ant nests. The case is made of a thin layer of soil firmly cemented together and, as the larva grows, built up, ring upon ring, from a shallow shell-like cover into a deep inverted cup. That of a mature larva is 12 to 14 mm long and 7 to 8 mm in diameter near the outer, rounded end and tapers uniformly to 5 to 6 mm at the open end, which is cut off square and held tightly against the wall by the enclosed larva. Before pupation this end is cemented to the wall and closed with a thin layer of cement just within the rim of the case. The larvae are most abundant in the older runways, especially those discolored by long use, where they apparently feed on the waxy accumulations from the ants.

⁸ Found in one nest in a mass of material discarded from the fungus gardens. They were in a number of loosely woven, silken tubes about 3 inches long and covered with bits of the waste material. Each tube contained a quickly moving, white larva, five-eighths of an inch long. Several of these were reared to the adult stage by placing them in a box with some of the waste material, on which they apparently feed. More larvae were later found in other nests at depths of about 8 feet, and adults were also collected at a depth of about 2 feet.

⁹ Adults of this large wasp were observed on several occasions flying around over the nests of *Atta texana*. Two of them were seen to enter ant nests. They flew about from entrance to entrance, examining each briefly; then, finally choosing one where the ants were quite active, disappeared into the tunnel. Several scoliid cocoons were found among the material from which *Cotinis* larvae were taken, hence it is possible that *Scolia guttata* is parasitic on this species.

SUMMARY

Atta texana, a fungus-growing ant found in Texas, Louisiana, and probably adjacent areas, is the most destructive species of the genus in this country. The ants from a single nest cause an estimated loss of from \$3 to \$4 annually on cereal and forage crops and much greater losses in orchard and truck crops.

The damage is due chiefly to the cutting of the green vegetation, which is taken into the nest and used as a medium on which to grow a fungus that constitutes the food of the ant.

Young are produced throughout the year, but chiefly in the summer. Sexual forms develop early in the spring. The mating flight is usually on a clear moonless night.

The colony includes many different forms and sizes of ants representing various castes—the sexual forms, soldiers, and workers of various sizes and with various specific duties.

A sandy soil underlaid with a stratum of clay seems to be preferred for the location of the nest, but nests are also found in heavy soils and in rocky hills.

The nests are often of very large size. Measurements of 12 nests showed an average area of 1,455 square feet and approximately 80 cubic feet of soil in the mounds. Other nests have been found as large as 4,500 square feet in area and one with 1,600 cubic feet of soil in the mounds.

In a nest excavated and examined in detail there were 911 cavities, 638 of which contained fungus gardens, and 40 cavities near the bottom of the nest were filled with waste materials from the gardens, and dead ants.

The control of this ant is complicated by the fact that there may be a number of queens in the nest. During the cool winter months the queens are concentrated in the center of the nest, but as the season becomes warmer each queen takes a portion of the workers to some more distant part of the nest to start a new center within the confines of the general nest.

Of the various materials tested, carbon disulphide was found to be the most effective both as a fungicide and as an insecticide, and hence the best material to use in the control of this ant. Several methods of application were tested, the best of which appear to offer a practical means of controlling this insect.

In the vicinity of San Antonio, Tex., the best time of the year to apply treatment was found to be from late in February to early in April. During this period the ground is warm enough for the carbon disulphide to vaporize readily and the queens are still concentrated in the center of the nest, so less material is required to kill out a colony at this time than later in the season.

About 50 species of insects and arachnids have been found within the nests in association with the ants. Larvae of *Cotinis longitarsis* feed on the waste material in the nest. It is suggested that orchardists might protect their fruit from the ravages of the *Cotinis* adults by controlling the leaf-cutting ant.

LITERATURE CITED

- (1) BELT, THOMAS.
1874. THE NATURALIST IN NICARAGUA: A NARRATIVE OF A RESIDENCE AT THE GOLD MINES OF CHONTALES; JOURNEYS IN THE SAVANNAHS AND FORESTS . . . 403 pp., illus. London.
- (2) BRAZIL MINISTERIO DA AGRICULTURA, DEPARTAMENTO NACIONAL DE PRODUÇÃO VEGETAL.
1936. DEMONSTRAÇÕES DE PROCESSOS DE COMBATE Á SAÚVA. 36 pp. Rio de Janeiro.
- (3) ESCHERICH, K.
1929. EINIGE NOTIZEN ÜBER DIE LEBENSWEISE, WIRTSCHAFTLICHE BEDEUTUNG UND BEKÄMPFUNG DER BLATTSCHNEIDERAMPEISEN (ATTA). Zool. Anz. 82: 185-197, illus.
- (4) HUNTER, WALTER DAVID.
1912. TWO DESTRUCTIVE TEXAS ANTS. U. S. Bur. Ent. Cir. 148, 7 pp.
- (5) JONES, THOMAS H.
1917. OCCURRENCE OF A FUNGUS-GROWING ANT IN LOUISIANA. (Sci. Note) Jour. Econ. Ent. 10: 561.
- (6) LEONARD, M. D.
1932. AN EARLY QUARANTINE IN PUERTO RICO. (Sci. Note) Jour. Econ. Ent. 25: 930-931.
- (7) MÖLLER, ALFRED.
1893. DIE PILZGARTEN EINIGER SÜDAMERIKANISCHER AMEISEN. 127 pp., illus. Jena.
- (8) OLIVEIRA, FILHO, M. L. DE.
1935. COMBATE Á SAÚVA. Bol. Agr. [Sao Paulo] (1934) 35: 541-610, illus. (Separate from Bol. Agr. No. 1, 1934, 72 pp., illus.)
- (9) SNYDER, T. E.
1937. DAMAGE TO YOUNG PINES BY A LEAF-CUTTING ANT, ATTA TEXANA BUCKLEY, IN LOUISIANA. La. Conserv. Rev., January 1937: 14-17, illus.
- (10) TANNER, J. EDWARD.
1892. OECODOMA OEPHALOTES. THE PARASOL OR LEAF-CUTTING ANT. Jour. Trinidad Field Nat. Club 1 (3): 68-69.
- (11) TOWNSEND, C. H. T.
1923. In Almanak Agricola Brasileiro. 12: 251.
- (12) WHEELER, WILLIAM MORTON.
1907. THE FUNGUS GROWING ANTS OF NORTH AMERICA. Bull. Amer. Mus. Nat. Hist. 23: 669-807, illus.
- (13) ————
1913. ANTS, THEIR STRUCTURE, DEVELOPMENT AND BEHAVIOR. 663 pp., illus. New York.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE WHEN THIS PUBLICATION WAS LAST PRINTED

<i>Secretary of Agriculture</i> -----	HENRY A. WALLACE.
<i>Under Secretary</i> -----	M. L. WILSON.
<i>Assistant Secretary</i> -----	HARRY L. BROWN.
<i>Coordinator of Land Use Planning and Director of Information</i> -----	M. S. EISENHOWER.
<i>Director of Extension Work</i> -----	C. W. WARBURTON.
<i>Director of Finance</i> -----	W. A. JUMP.
<i>Director of Personnel</i> -----	ROY F. HENDRICKSON.
<i>Director of Research</i> -----	JAMES T. JARDINE.
<i>Solicitor</i> -----	MASTIN G. WHITE.
<i>Agricultural Adjustment Administration</i> -----	H. R. TOLLEY, <i>Administrator</i> .
<i>Bureau of Agricultural Economics</i> -----	A. G. BLACK, <i>Chief</i> .
<i>Bureau of Agricultural Engineering</i> -----	S. H. McCORRY, <i>Chief</i> .
<i>Bureau of Animal Industry</i> -----	JOHN R. MOHLER, <i>Chief</i> .
<i>Bureau of Biological Survey</i> -----	IRA N. GABRIELSON, <i>Chief</i> .
<i>Bureau of Chemistry and Soils</i> -----	HENRY G. KNIGHT, <i>Chief</i> .
<i>Commodity Exchange Administration</i> -----	J. W. T. DUVEL, <i>Chief</i> .
<i>Bureau of Dairy Industry</i> -----	O. E. REED, <i>Chief</i> .
<i>Bureau of Entomology and Plant Quarantine</i> -----	LEE A. STRONG, <i>Chief</i> .
<i>Office of Experiment Stations</i> -----	JAMES T. JARDINE, <i>Chief</i> .
<i>Farm Security Administration</i> -----	W. W. ALEXANDER, <i>Administrator</i> .
<i>Food and Drug Administration</i> -----	WALTER G. CAMPBELL, <i>Chief</i> .
<i>Forest Service</i> -----	FERDINAND A. SILCOX, <i>Chief</i> .
<i>Bureau of Home Economics</i> -----	LOUISE STANLEY, <i>Chief</i> .
<i>Library</i> -----	CLARIBEL R. BARNETT, <i>Librarian</i> .
<i>Bureau of Plant Industry</i> -----	FREDERICK D. RICHEY, <i>Chief</i> .
<i>Bureau of Public Roads</i> -----	THOMAS H. MACDONALD, <i>Chief</i> .
<i>Soil Conservation Service</i> -----	H. H. BENNETT, <i>Chief</i> .
<i>Weather Bureau</i> -----	C. C. CLARK, <i>Acting Chief</i> .

This bulletin is a contribution from

<i>Bureau of Entomology and Plant Quarantine</i> -----	LEE A. STRONG, <i>Chief</i> .
<i>Division of Cereal and Forage Insect Investigations</i> -----	C. M. PACKARD, <i>Principal Entomologist, in Charge</i> .

